



CCS 2018 Summer School

Monitoring and Understanding Sea Level from Space

Carmen Boening

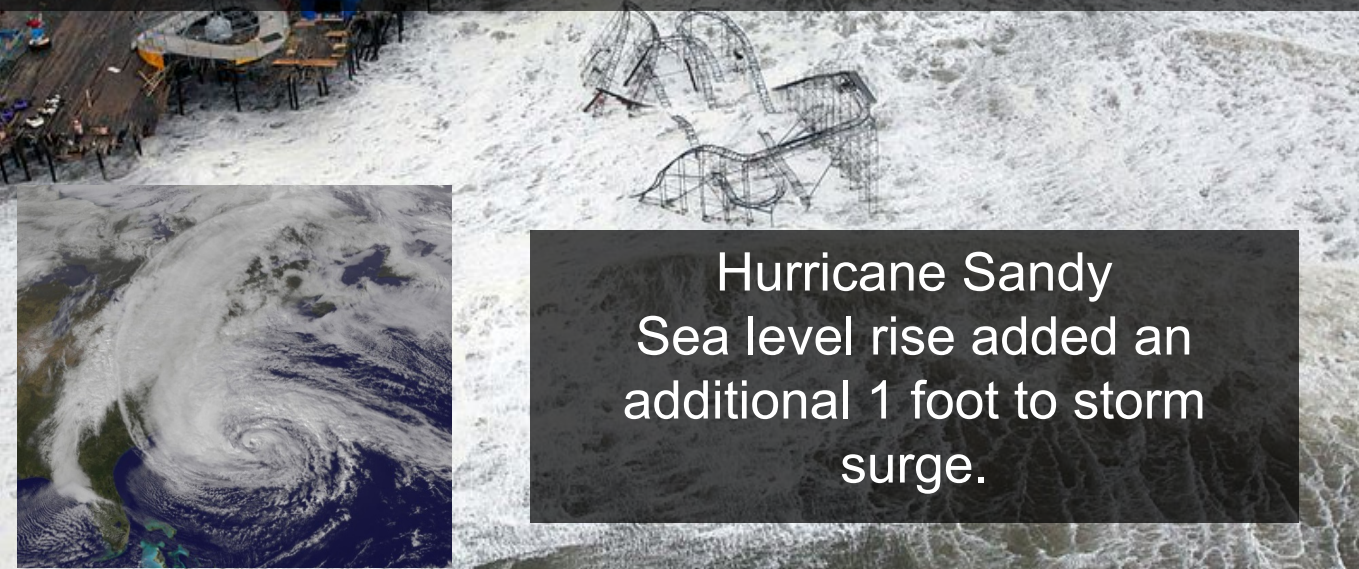


Jet Propulsion Laboratory
California Institute of Technology

Why are we interested in sea level changes?

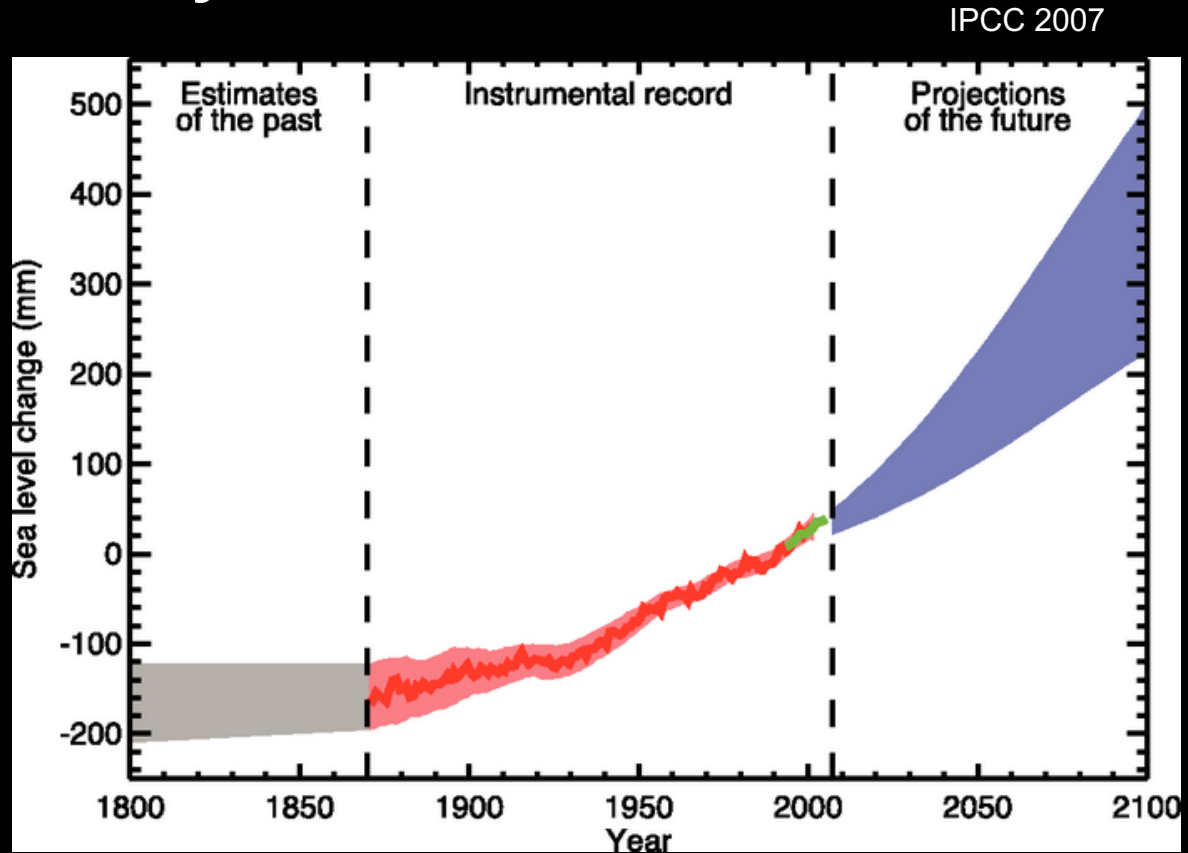
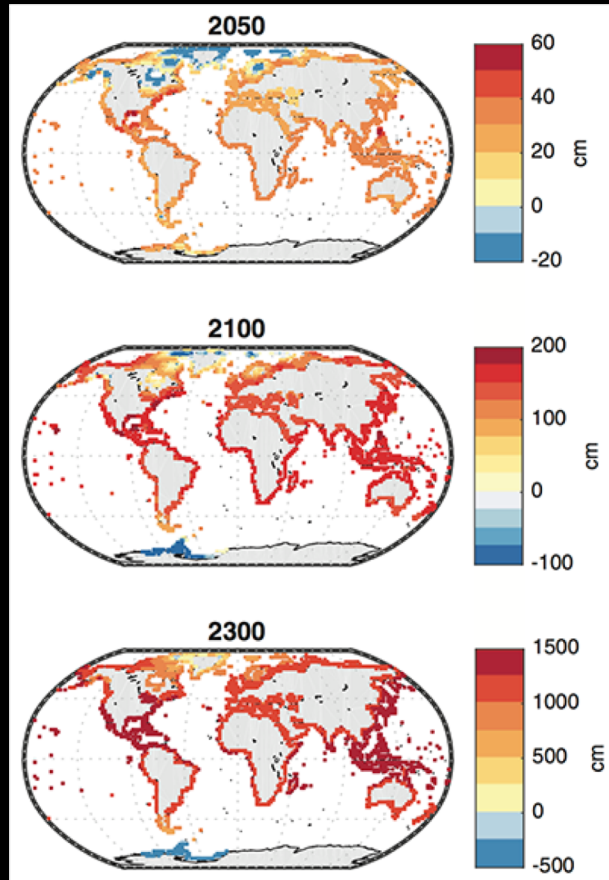
Worldwide, ~150 million people (5m in US) live within zones at risk from just 1 meter (~3 ft) of sea level rise

Mitigation costs in the billions of dollars (For example, shoreline retreat in the United States is projected to cost between USD 270 billion to 475 billion for each meter of sea level rise)

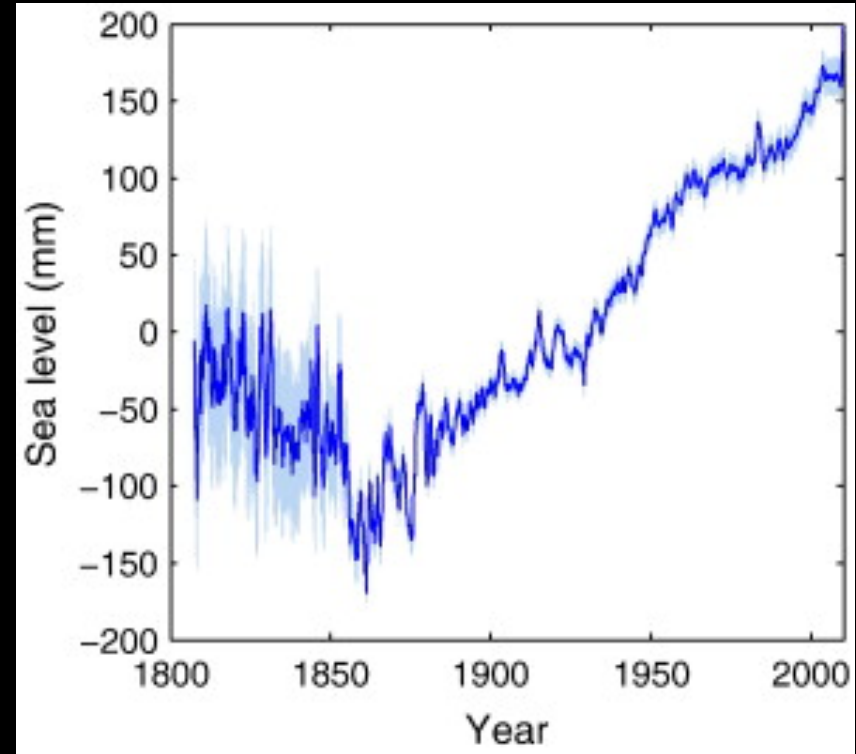
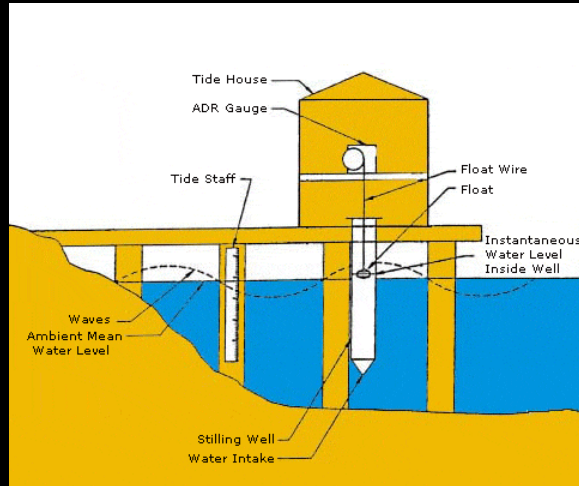
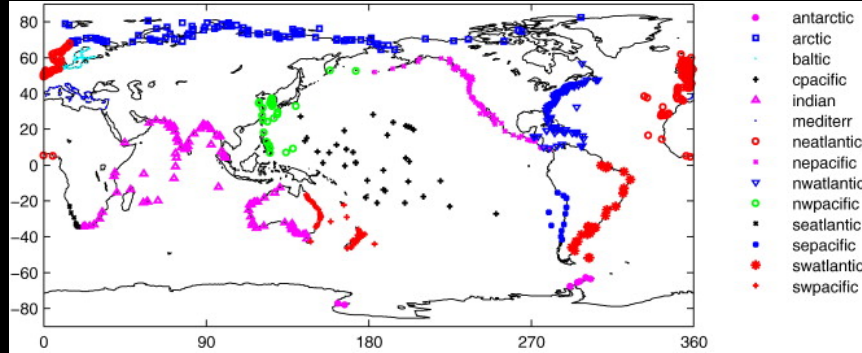


Hurricane Sandy
Sea level rise added an additional 1 foot to storm surge.

What do the predictions say?



How do we measure sea level change?



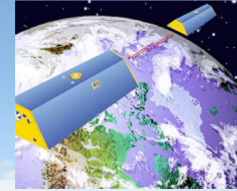
Jevrejiva et al., 2014

How do we measure sea level from space?



Jason series measures
sea surface height
changes since 1992

Sea Level Change



GRACE measures
water mass
changes since 2002

$$h_{\text{total}} = h_{\text{mass}} + h_{\text{density}}$$

Runoff from land
hydrology adds
ocean mass

Warming water
leads to
(thermal)
expansion

Melting ice
adds to
ocean
mass

Sea Surface Height Measurements – TOPEX/Poseidon Jason - Technique

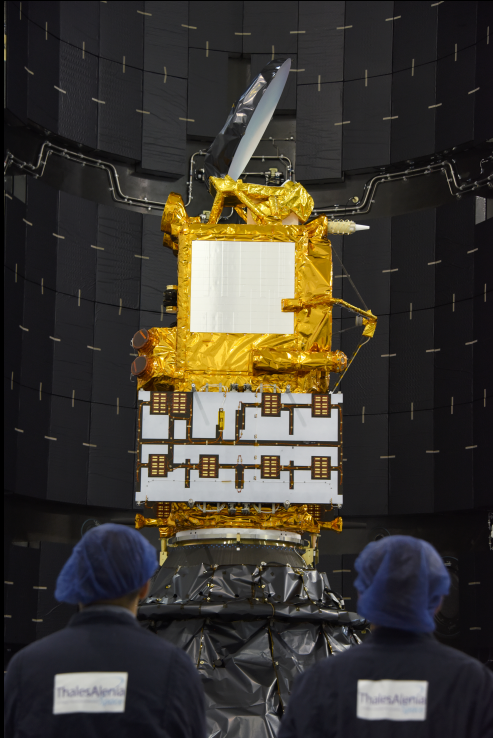
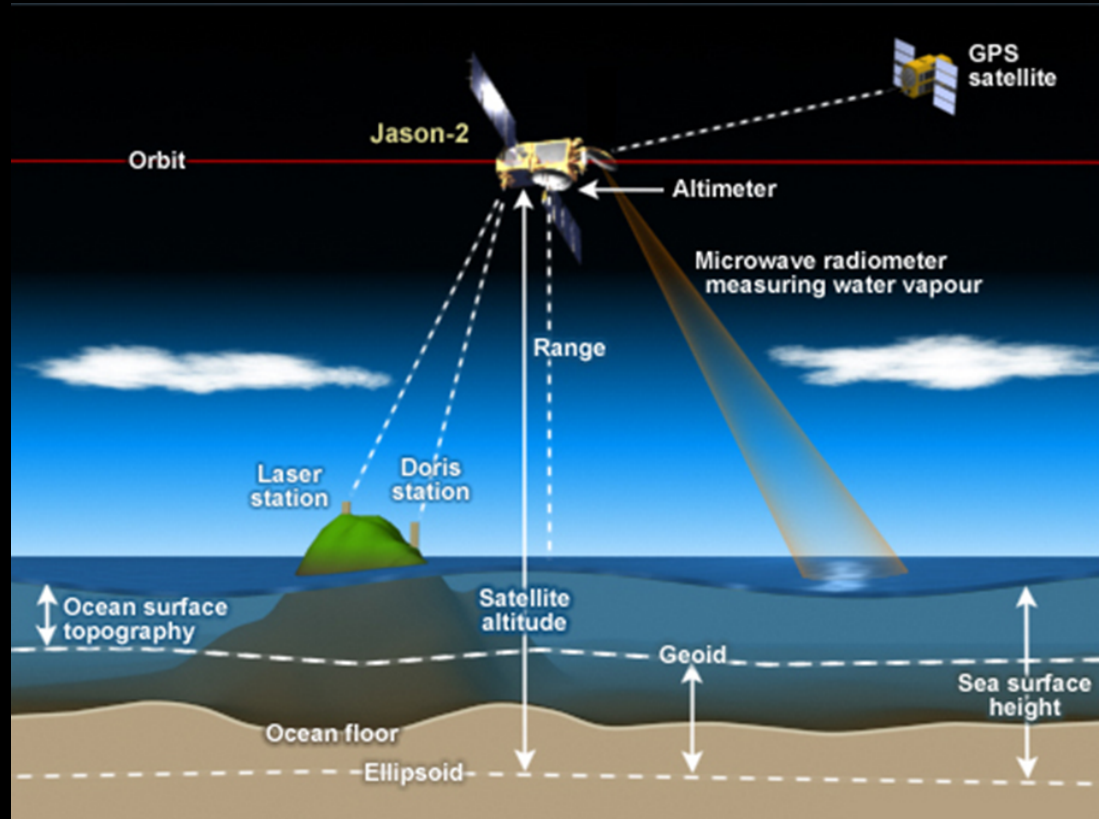
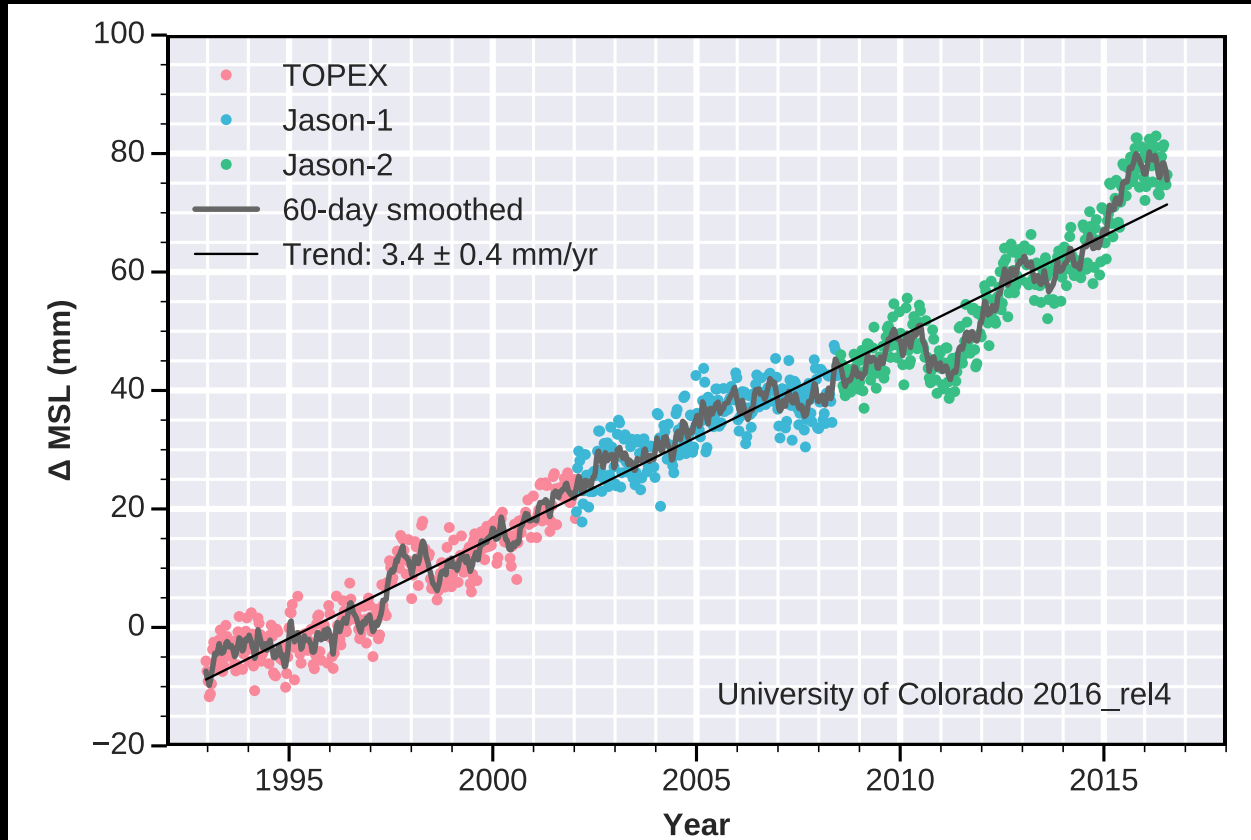


Image Credit: NASA



Global Mean Sea Level



Mass Measurements – GRACE and GRACE-Follow On - Technique

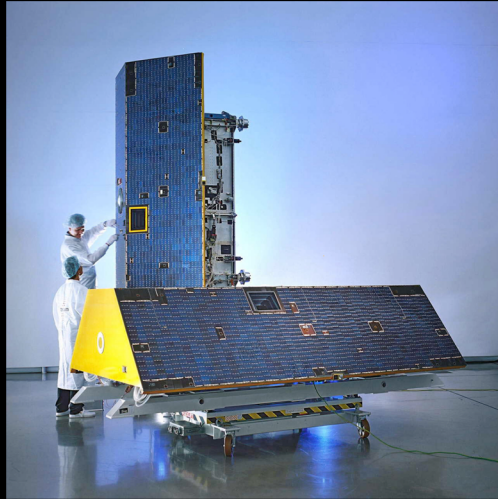
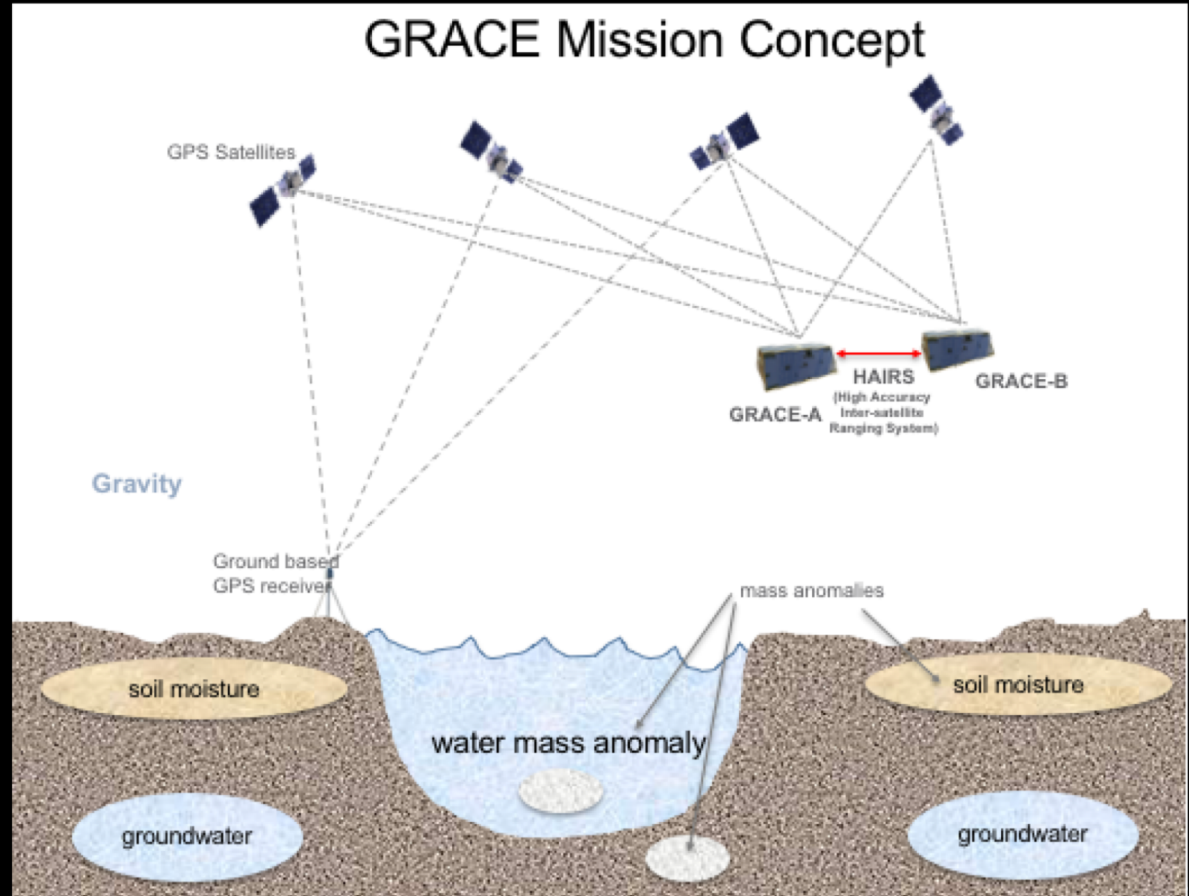
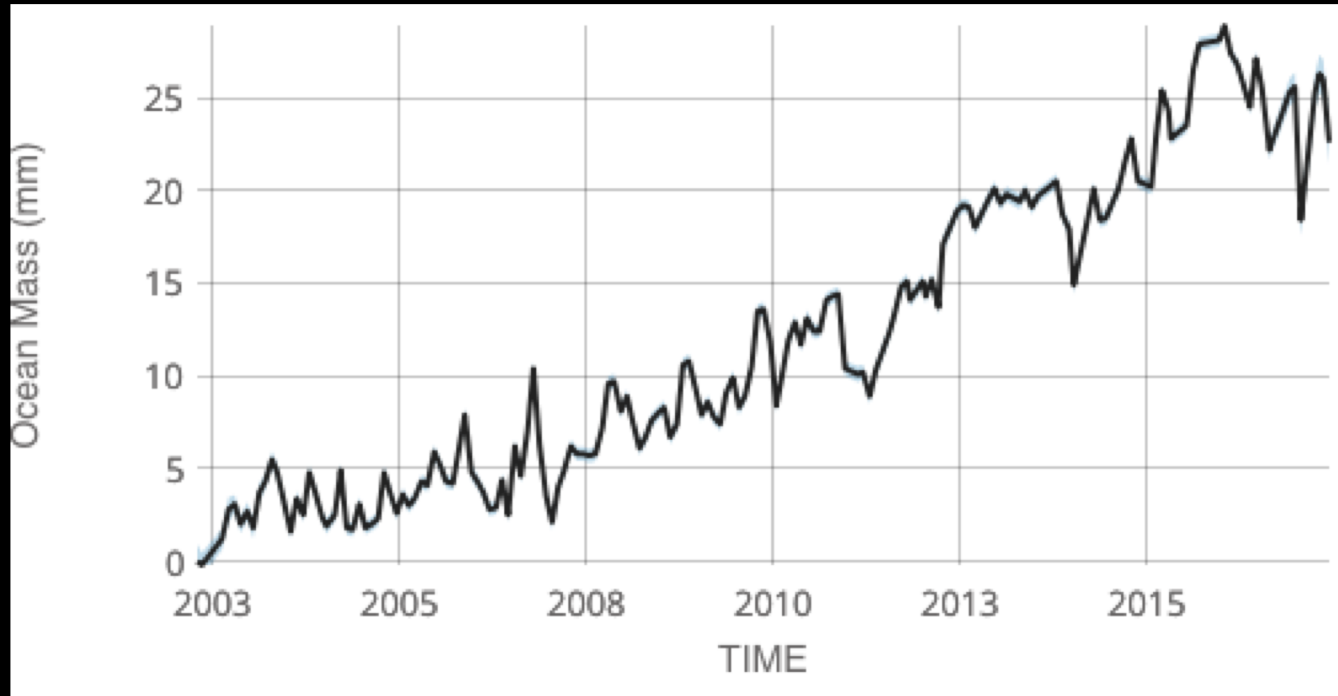


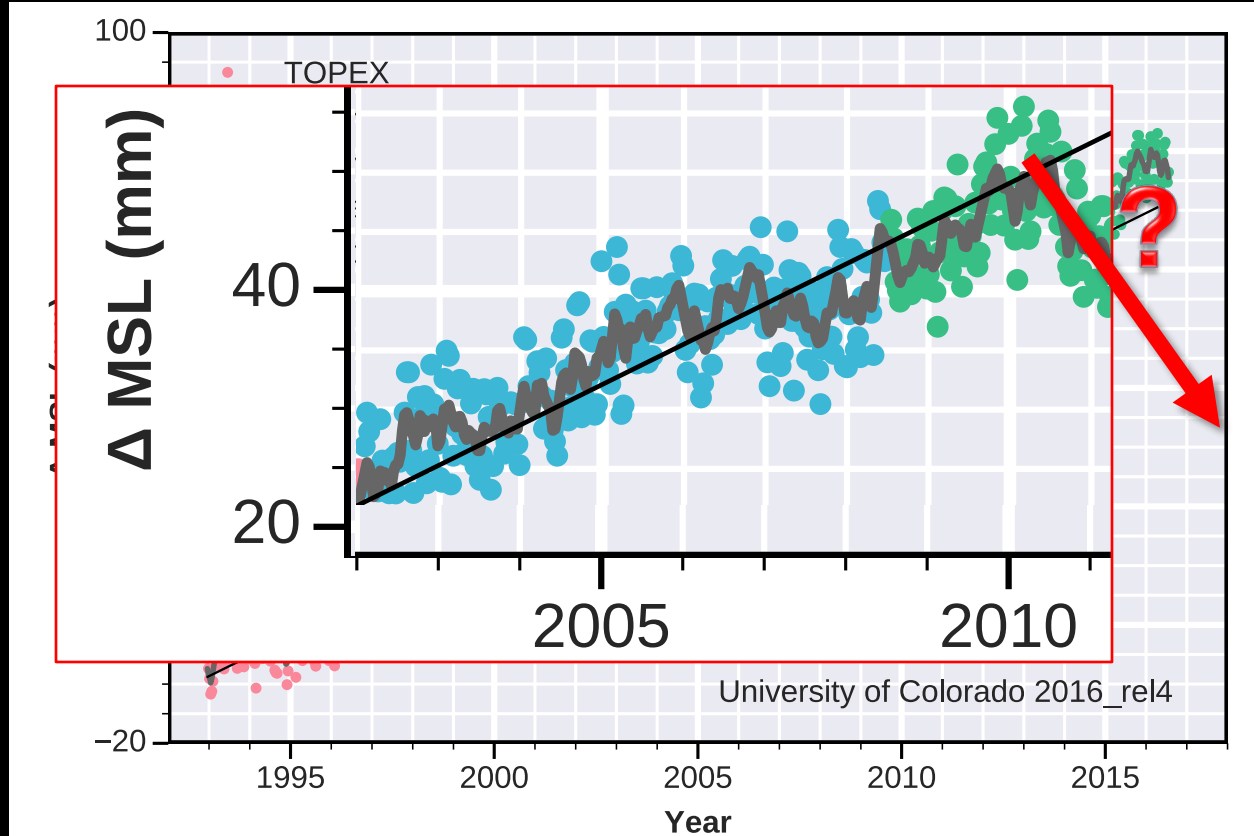
Image Credit: Airbus



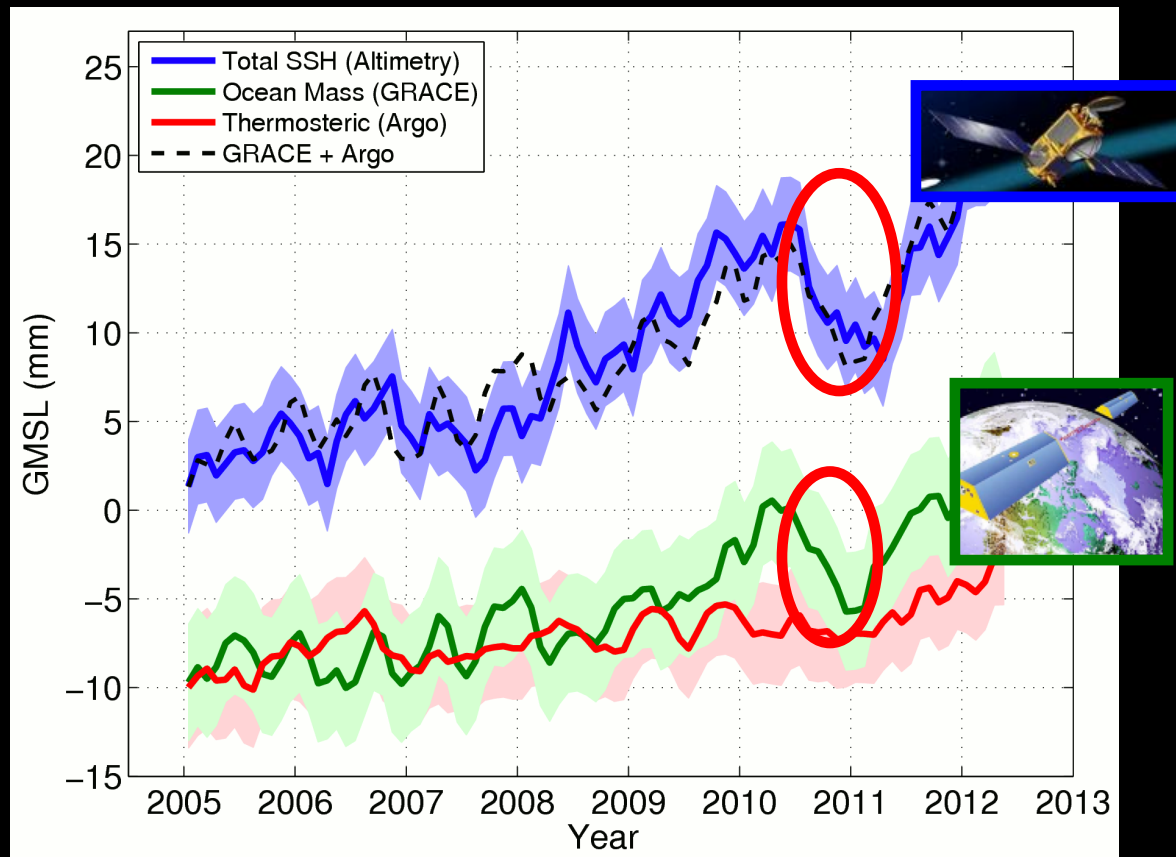
Global Mean Ocean Mass



Records of sea level change since 1992

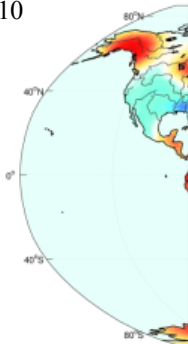


Using Multiple Satellites to “Track” Water



Terrestrial Water Storage in 2010 and 2011

2009-10



2010-11



water accumulates in Australia's Warburton Creek in late 2010

Units: [mm-H₂O]
Mass in millimeter of water thickness

ACE water
s from 2010
ates more
tralia and
n America.

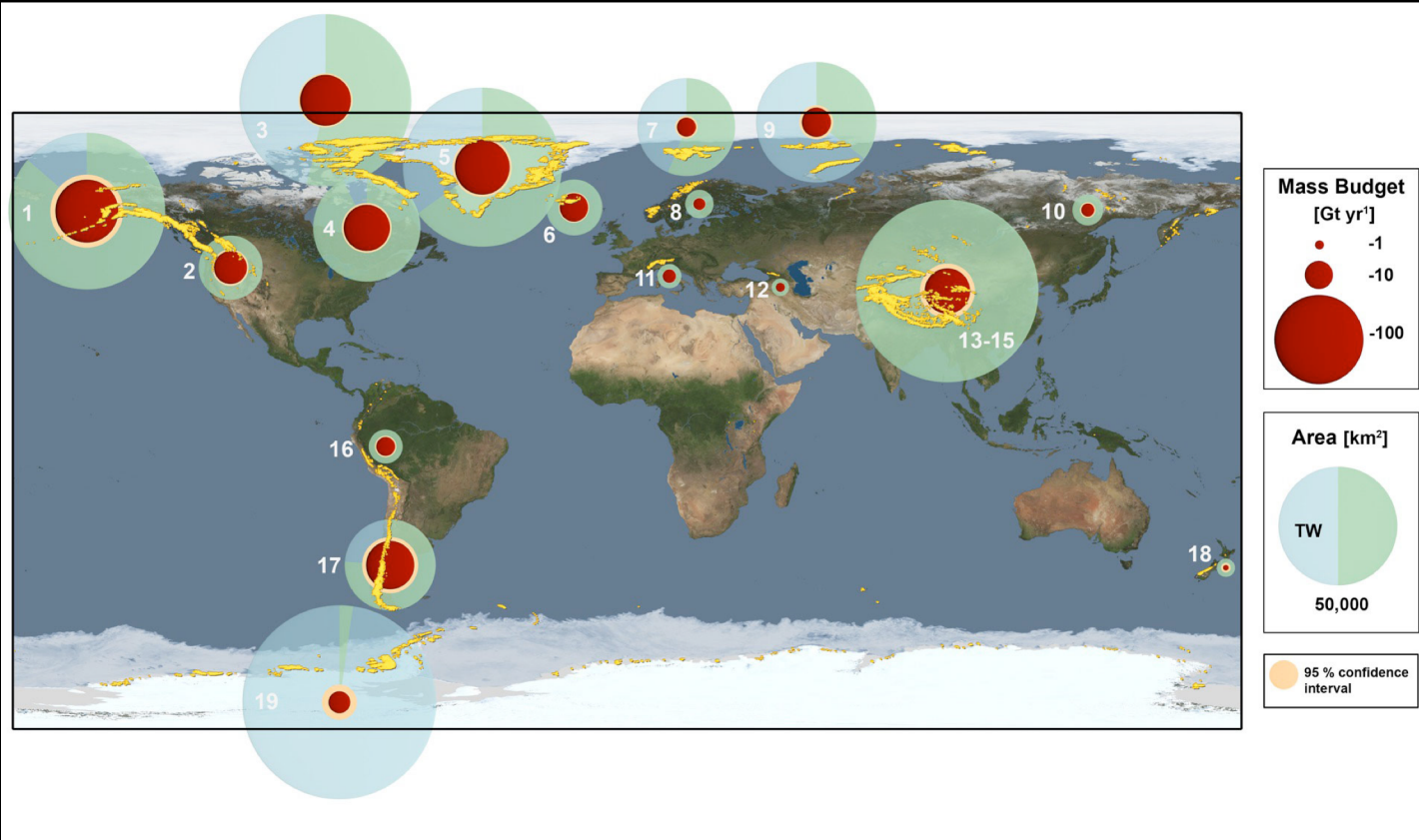
Boening et al., 2012

Arapaho Glacier (Boulder, CO)



Weighing Glacial Melt

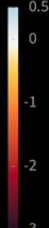
- 198,000 glaciers in the world
- Cover an area of 726,000 km²
- 1/3 of current sea level rise



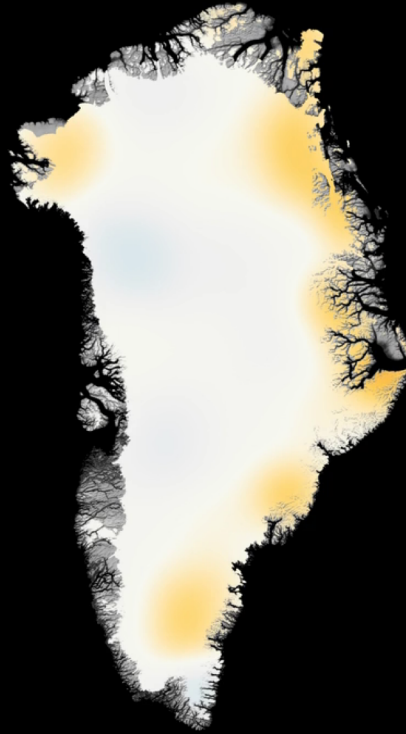
Ice Sheet Loss affecting sea level

GREENLAND ICE MASS LOSS
2003-2013

Change in Ice Mass since 2003
equivalent water height (meters)

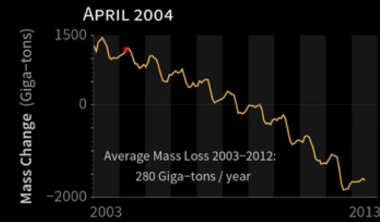


A vertical color scale bar ranging from 0.5 at the top to -3 at the bottom. The colors transition from yellow at the top, through orange and red, to dark red at the bottom.

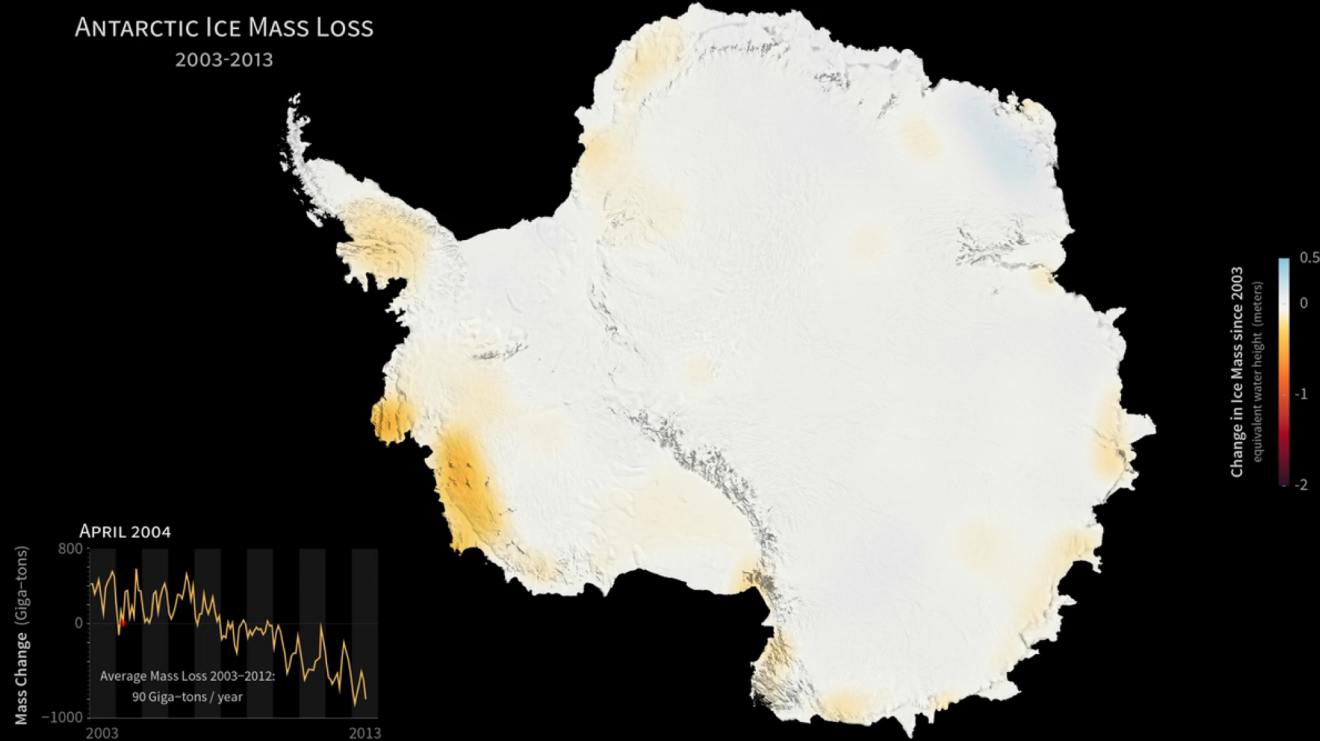


Greenland: ~7 m sea level eqv.
Antarctica: ~60 m sea level eqv.

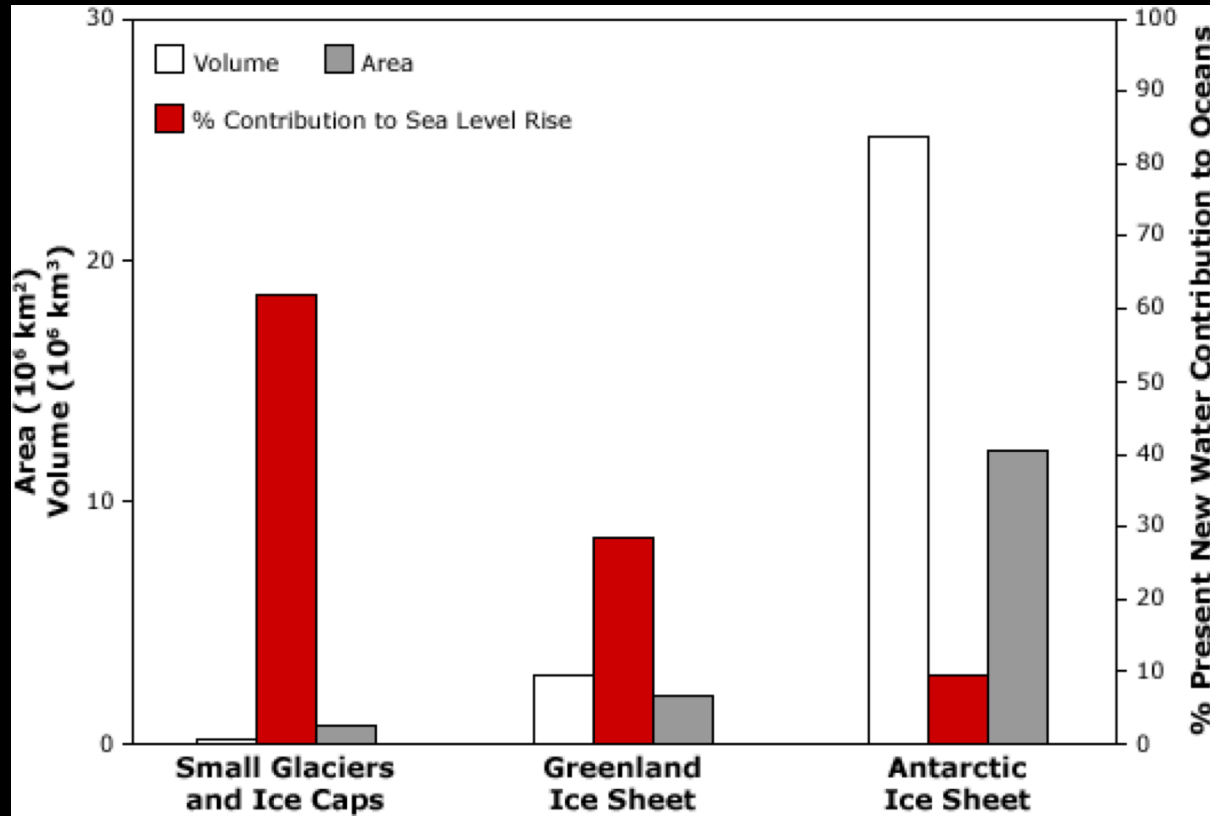
*GRACE weighs the ice sheets
and identifies loss and gain on
regional level*



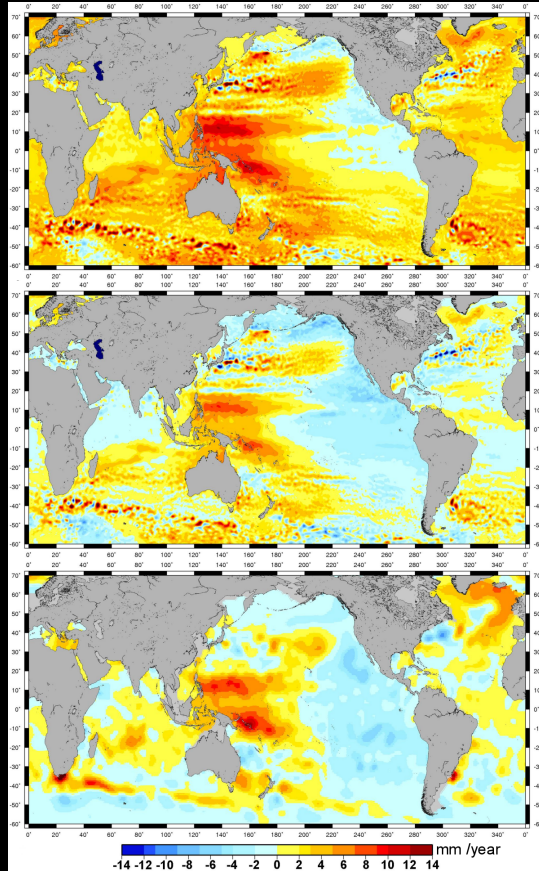
Ice Sheet Loss affecting sea level



Percentage contribution to Sea Level Rise



Regional changes

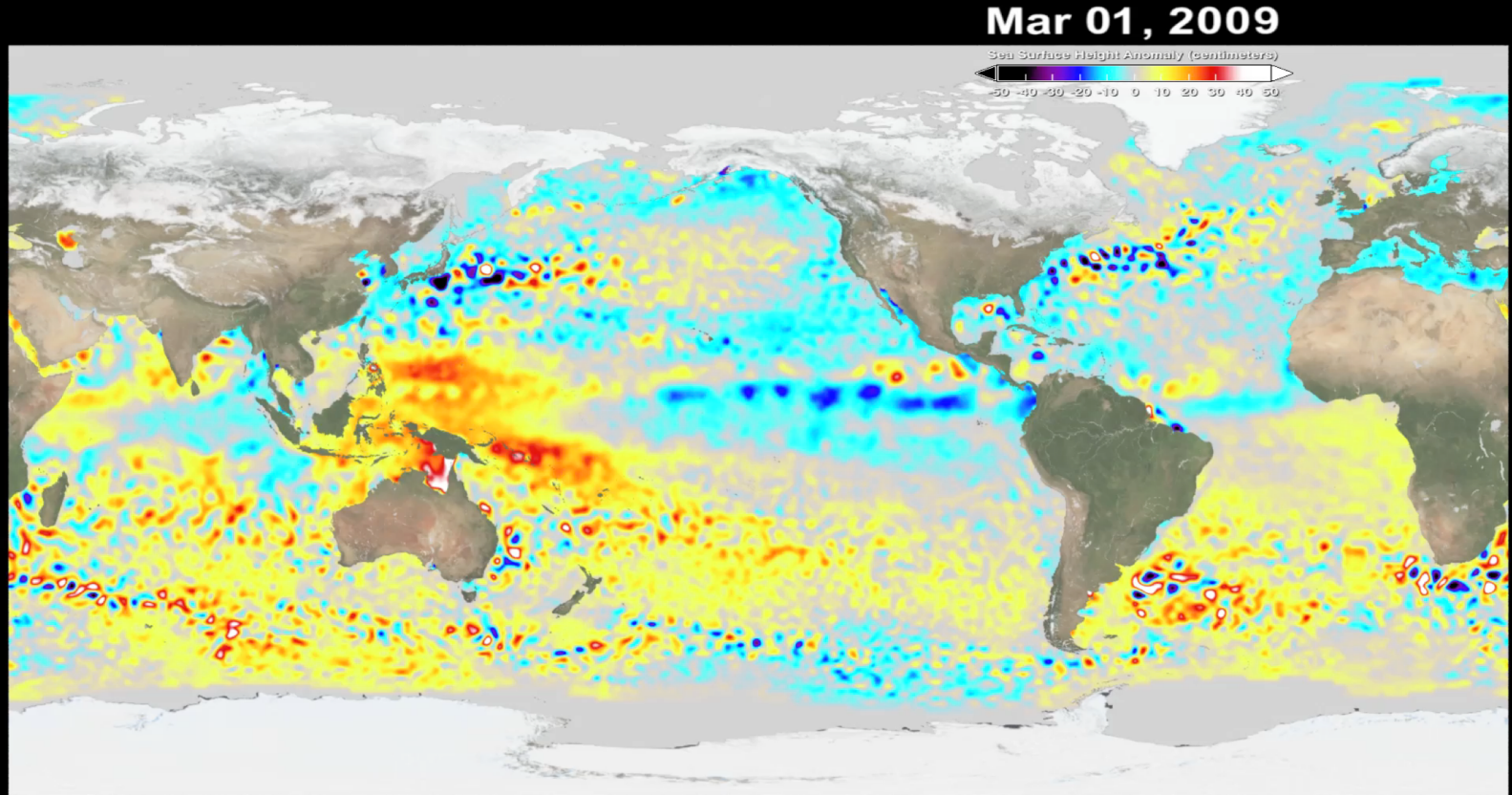


Total Sea Level change

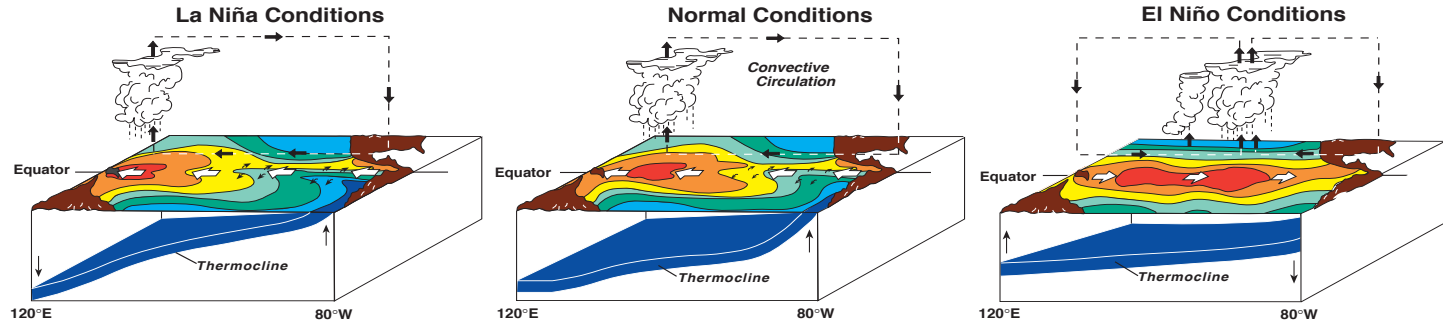
Total Sea Level change
w/o the global trend

Steric Sea Level change

Regional Differences

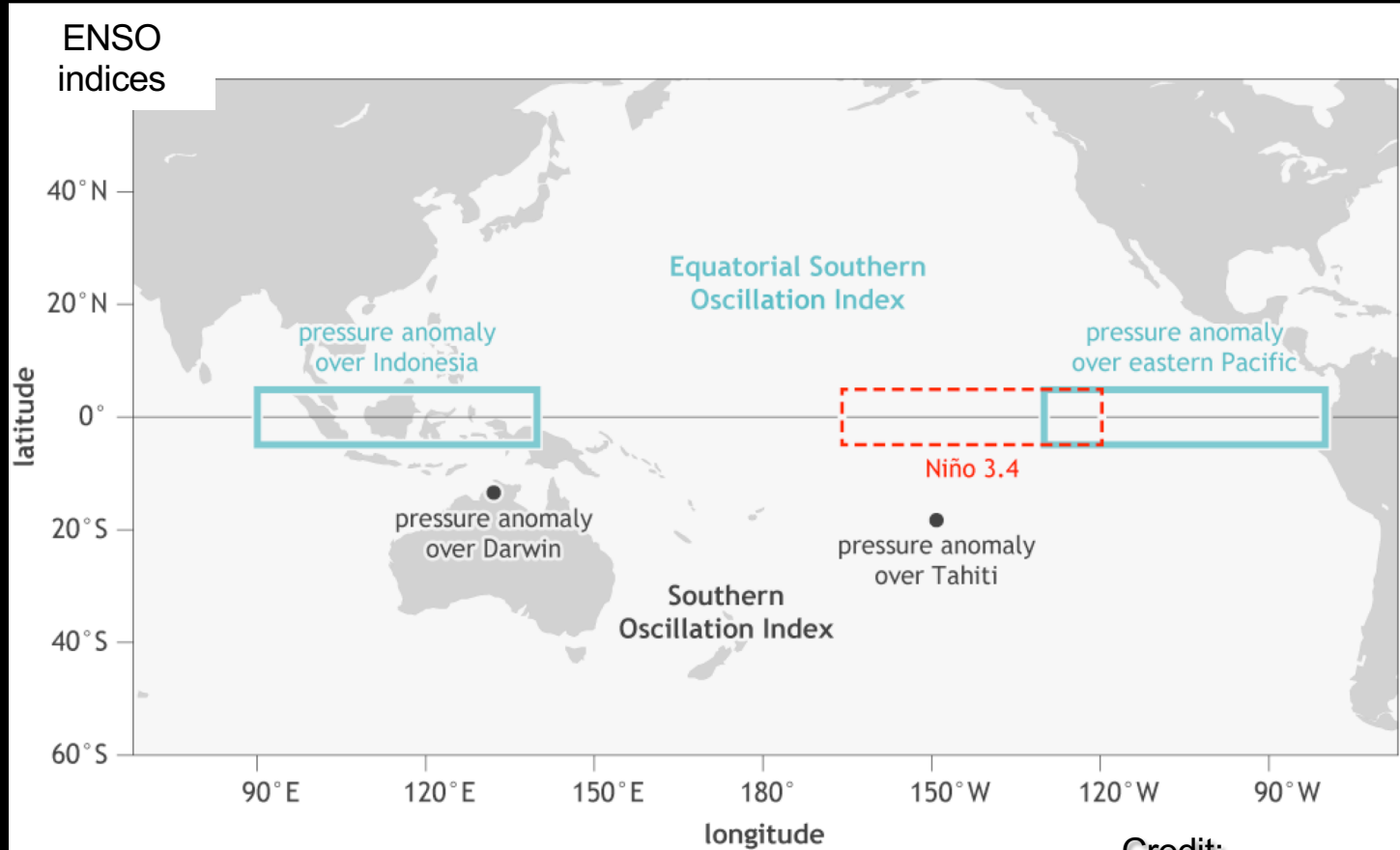


What is the El Niño Southern Oscillation?

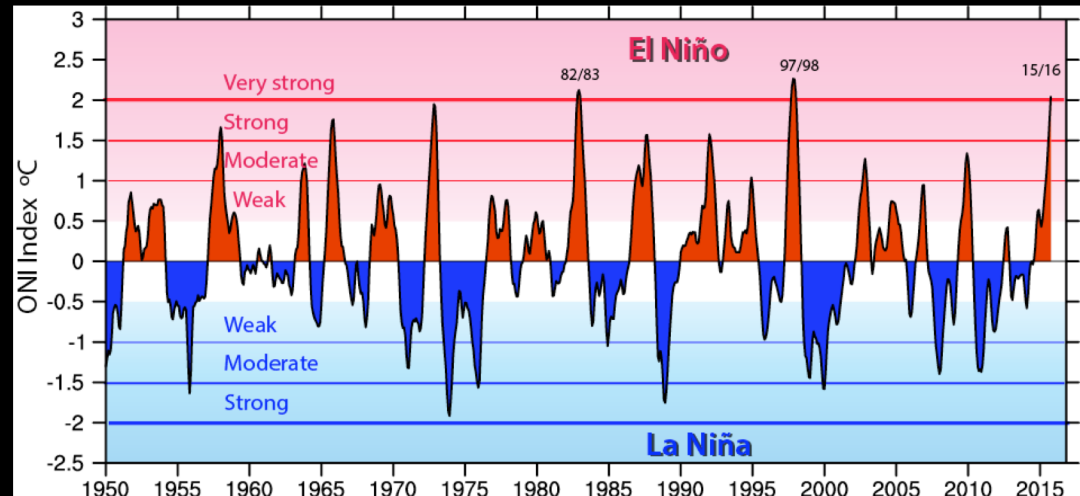
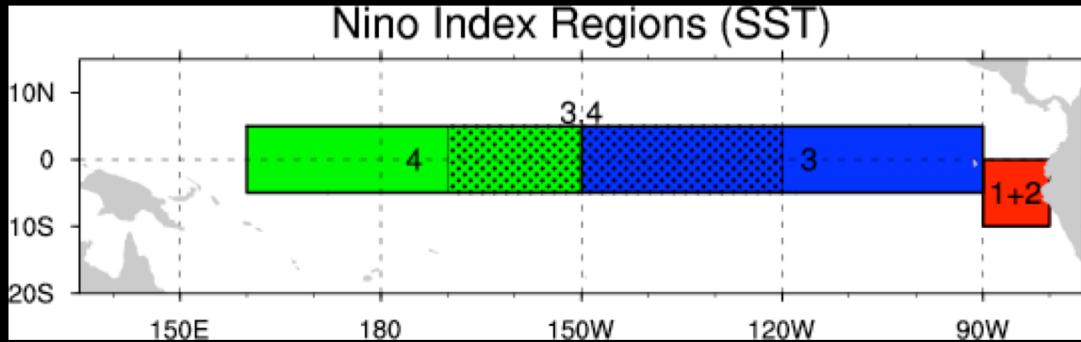


“**El Niño–Southern Oscillation (ENSO)** is an irregularly periodical variation in [winds](#) and [sea surface temperatures](#) over the tropical eastern Pacific Ocean. The warming phase is known as [El Niño](#) and the cooling phase as [La Niña](#). *Southern Oscillation* is the accompanying atmospheric component, coupled with the sea temperature change: *El Niño* is accompanied with high, and *La Niña* with low air [surface pressure](#) in the tropical western Pacific. The two periods last several months each (typically occur every few years) and their effects vary in intensity.”

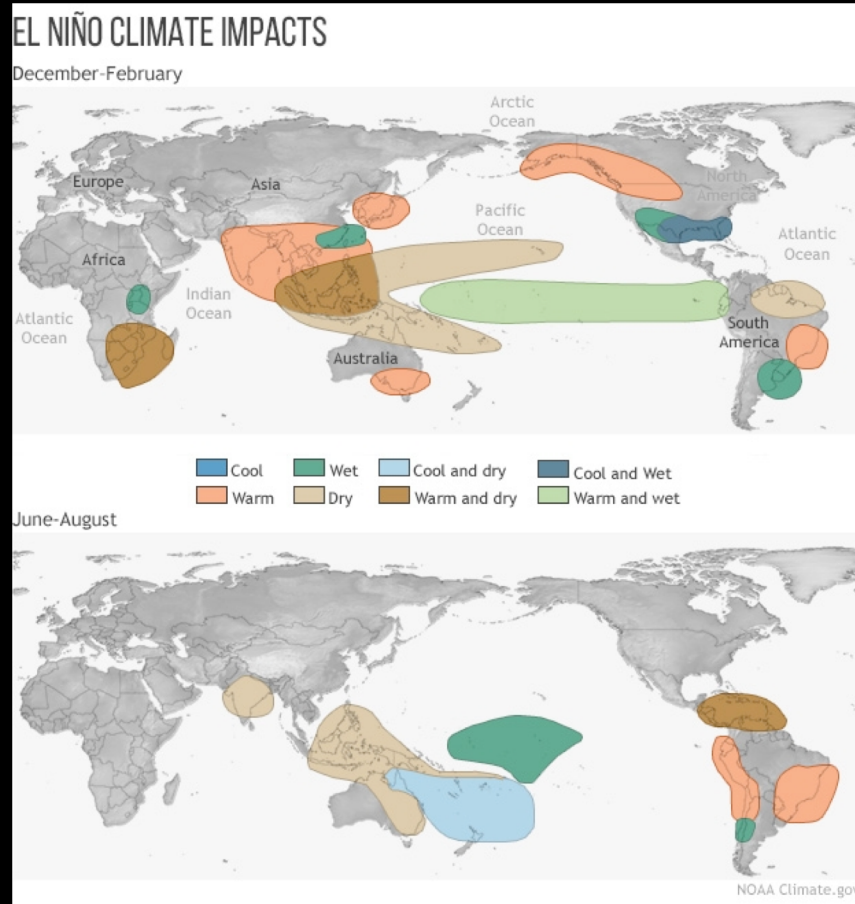
Definition of ENSO



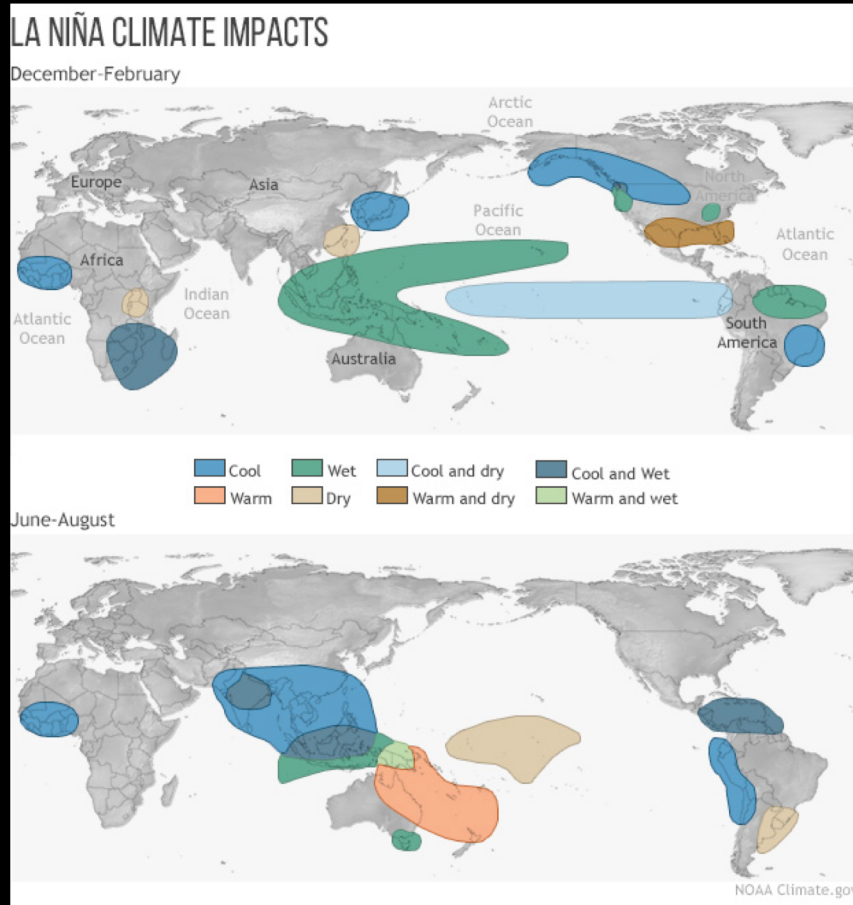
Definition of ENSO



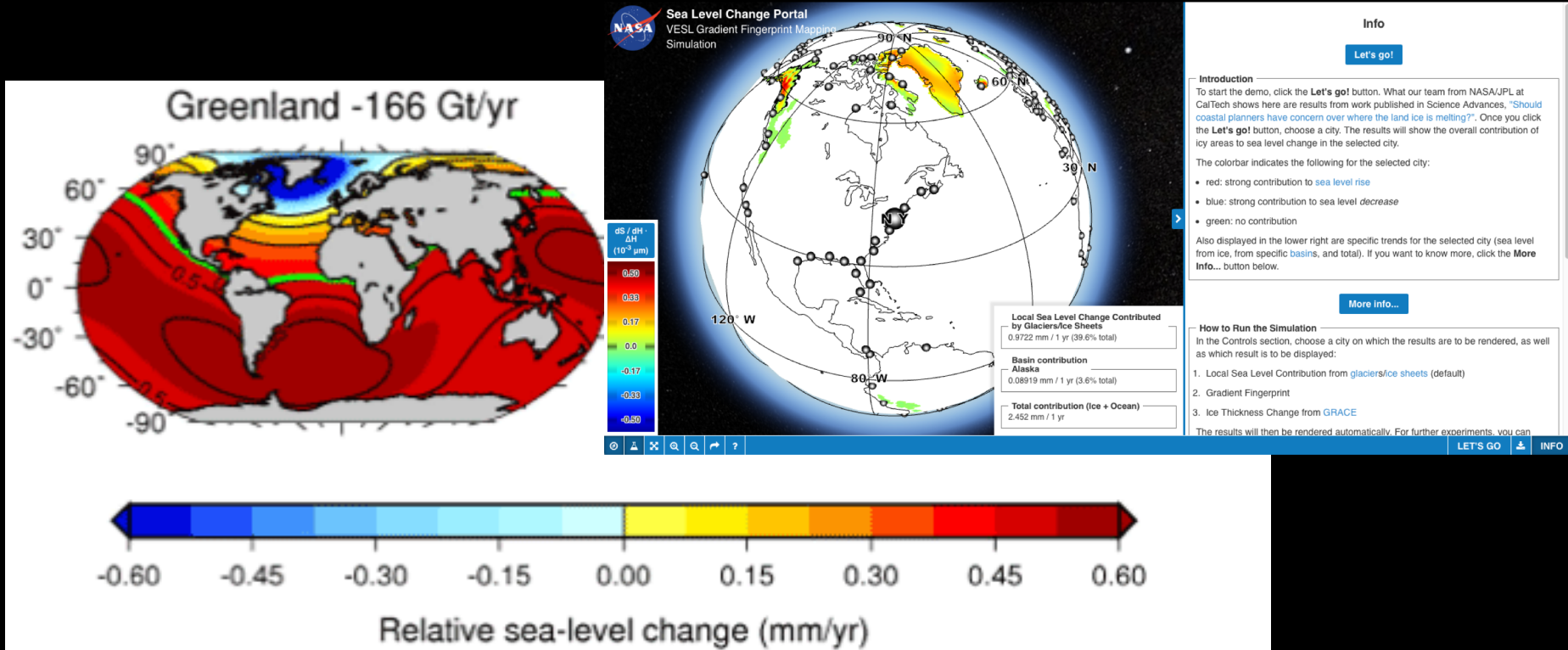
How does it affect us?



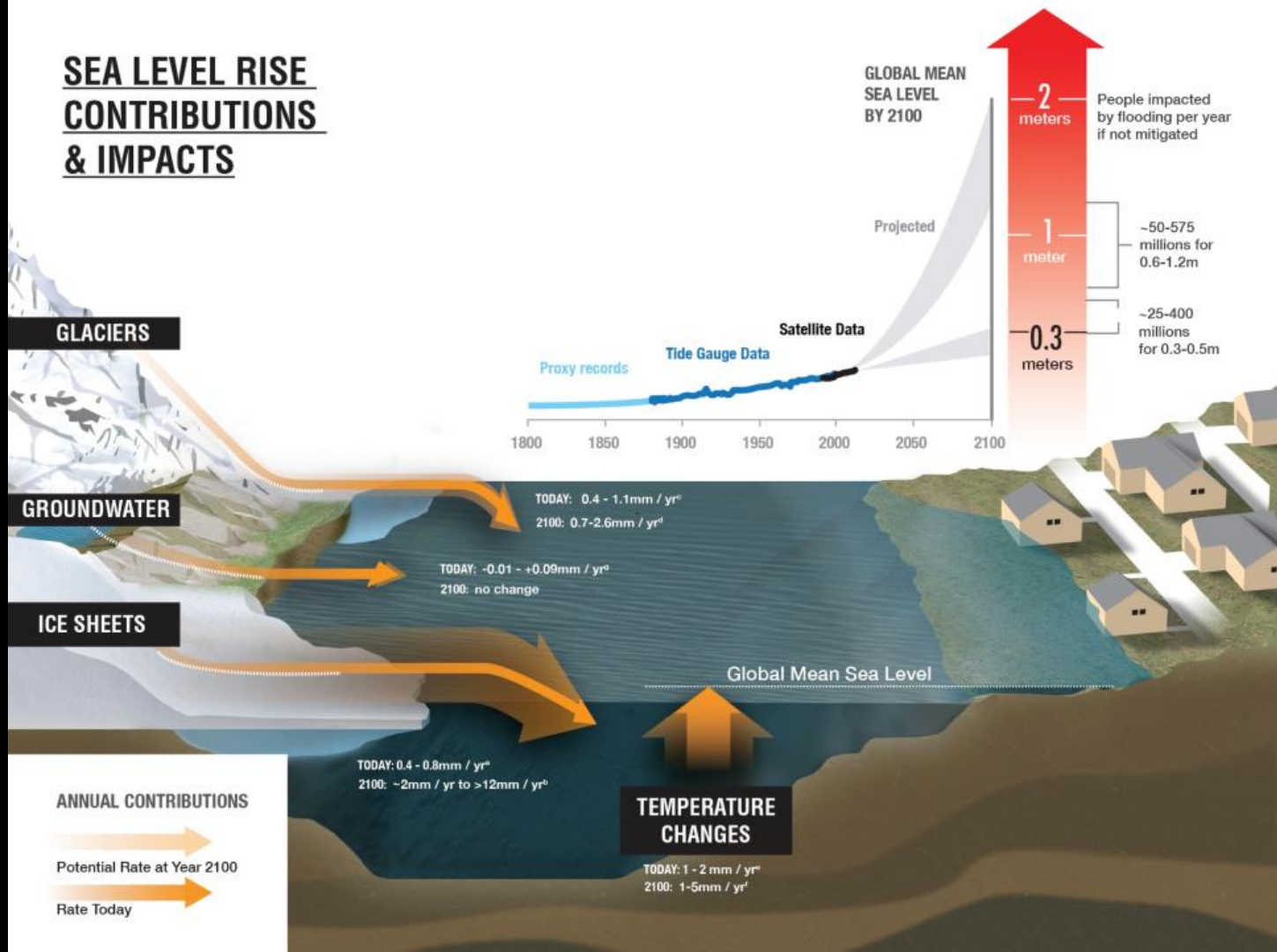
How does it affect us?



Sea Level Fingerprints

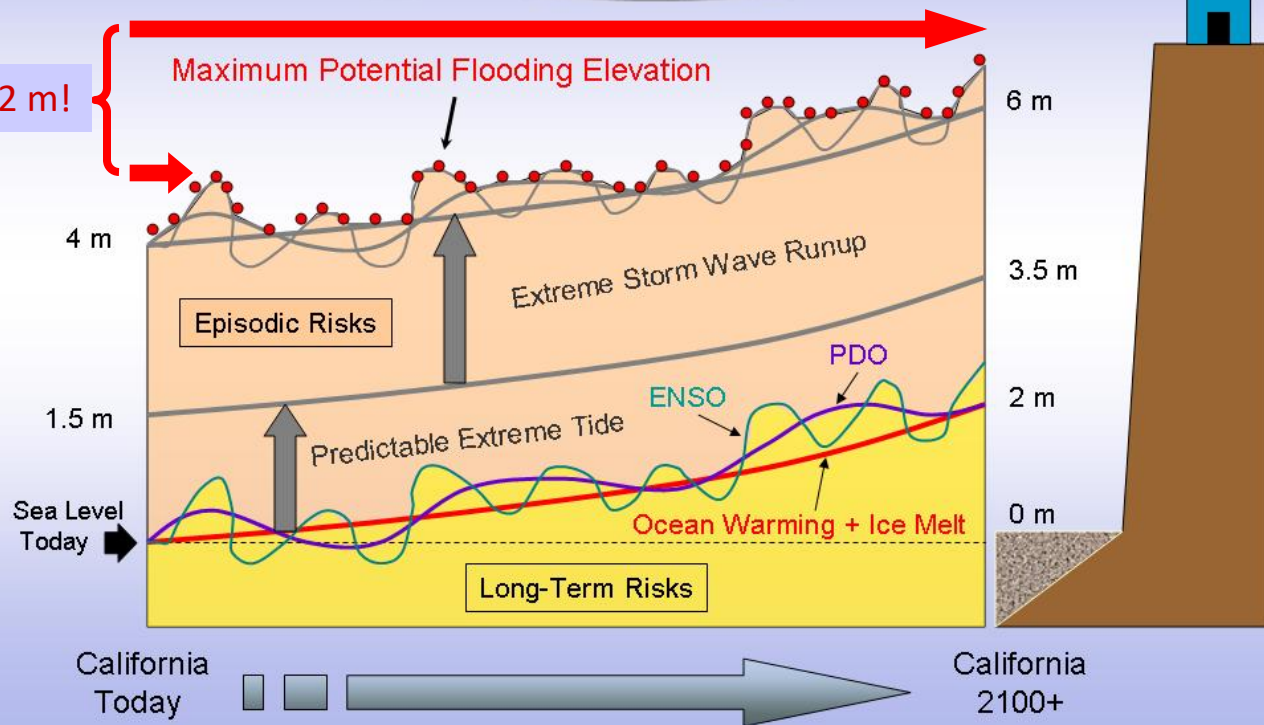


SEA LEVEL RISE CONTRIBUTIONS & IMPACTS



Flooding and Beach and Cliff Losses from Combinations of
Sea Level Rise, Climate Variability, Tides, Waves, and Runup

Extra 2 m!



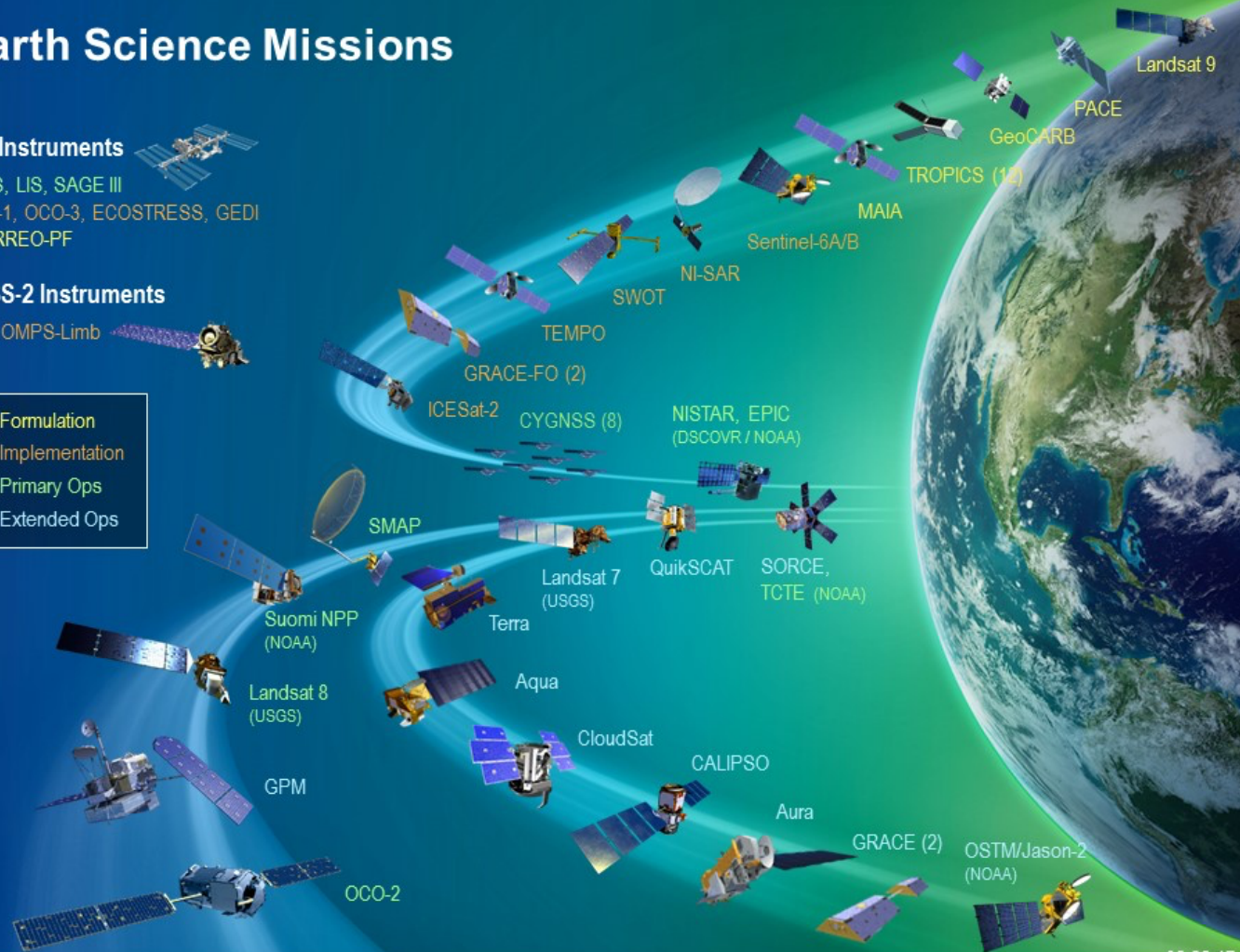
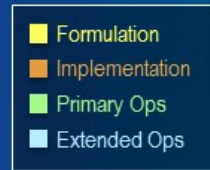
Earth Science Missions

ISS Instruments

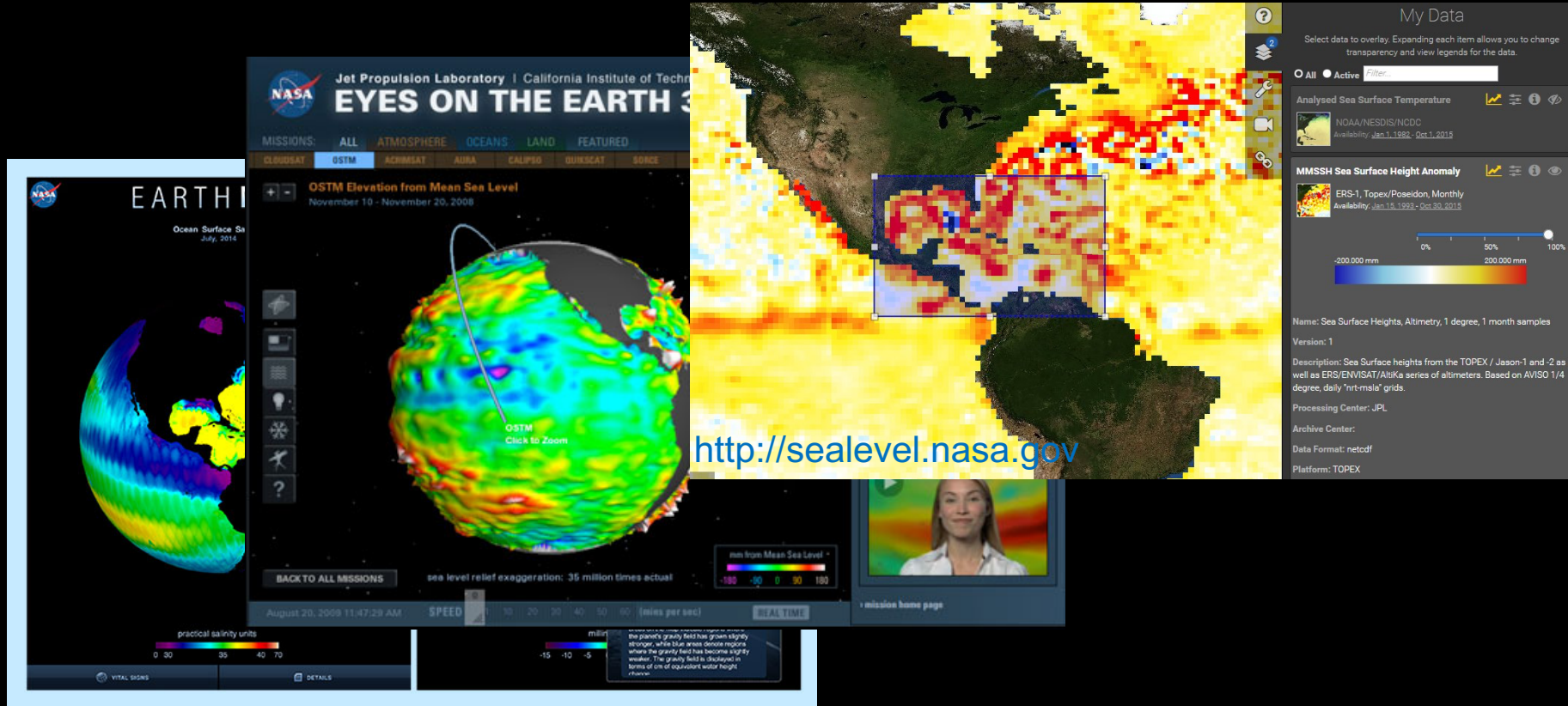
CATS, LIS, SAGE III
TSIS-1, OCO-3, ECOSTRESS, GEDI
CLARREO-PF

JPSS-2 Instruments

RBI, OMPS-Limb



Looking at NASA (sea level) data





Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov

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Click on “**Home Tab**,” then click on the downward arrow next to the “**New Slide**” icon located on the left corner of the menu bar.



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